NRCan IGS Analysis Center Report for 2001

C. Huot, B. Donahue, Y. Mireault, P. Tétreault, P. Héroux and D. Hutchison

Geodetic Survey Division
Natural Resources Canada
Ottawa, Canada

Summary

The year 2001 marked a period of many changes in the NRCan processing strategy used for IGS product generation. Implementing version 2.6 of the GIPSY-OASIS software to estimate our Final and Rapid products significantly reduced processing time and allowed for the estimation and submission of Rapid station and satellite clocks at 5-minute interval. Improvement in the Ultra-Rapid pole estimates reduced the noise of the EMU ERP series. Since May 2001, resolving the ambiguities in the Regional solutions improved station coordinate estimates by 1mm. Regional solutions are being submitted to NAREF (North American Reference Frame) on a regular basis since January 2001. More details on these changes and other improvements can be found in the following report.

NRCan Final and Rapid Products

During 2001, NRCan continued to estimate Rapid and Final products as described in ftp://igscb.jpl.nasa.gov/igscb/center/analysis/emr.acn. Several changes, shown in Table 1, were made to the NRCan strategy based on IGS recommendations. Efforts were devoted to upgrading computer hardware and implementing version 2.6 of JPL's GIPSY-OASIS software. These changes have significantly decreased the processing time required for both Rapid and Final product generation and have allowed us to begin using 5 minute sampling to produce Rapid satellite and station clocks at 5 minute intervals.

IGS 2000 Reference Frame

Beginning with GPS week 1143 (December 2, 2001), a-priori station coordinates and velocities were changed from IGS97 (IGS realization of ITRF 97) to IGS00 (IGS realization of ITRF 2000). IGS00, determined by the IGS Reference Frame Coordinator, is derived from a subset of 54 stations extracted from the IGS cumulative combined solution IGS01P37.snx stored in IGS01P37_RS54.SNX. In our Final solution, the coordinates of a subset of these 54 reference stations are loosely constrained (10m) while in our Rapid solution tightly constrains the coordinates to their IGS01P37_RS54.SNX sigmas. Table 2 shows the effects of the reference frame change on various NRCan Rapid products for GPS week 1157.

GIPSY-OASIS Version 2.6

Version 2.6 of JPL's GIPSY-OASIS software was in place for the estimation of NRCan Final products starting with GPS week 1139, and for the Rapid products starting with GPS week 1142. Improvements made by JPL to the GIPSY-OASIS filtering algorithm has decreased the processing time for NRCan Rapid product estimation by 2-3 hours. The reduction in processing time was largely responsible for the marked increase in the number of days that the NRCan Rapid solution was ready on time to contribute to the IGR combination. The new version of GIPSY-OASIS has also improved the consistency of the Rapid and Final solutions with respect to IGS. Figure 1 shows the NRCan Rapid orbit daily RMS with respect to the IGR combination. Figure 2 shows the NRCan Final orbit RMS with respect to the IGS combination. Currently developments are underway to further increase the consistency of NRCan Rapid and Final products in 2002.

NRCan Regional Solution

During 2001, NRCan continued to process all stations of the Canadian Active Control System (CACS) in support of the Canadian Spatial Reference System (CSRS) realization and as part of the densification of the ITRF reference frame in North America. Version 2.5 of JPL's GIPSY-OASIS is used along with other software developed in-house to produce weekly combined SINEX station coordinates files which are submitted to NAREF for combination.

Processing Strategy

In 2001, three new stations were added to the processing, namely Baker Lake (BAKE, Northwest Territories), Holman (HOLM, Northwest Territories) and Val D'Or (VALD, Quebec). Station THU1, which was one of the 6 anchor stations, was removed due to poor data quality. This brought the total to 31 stations with 5 anchor stations (ALGO, DRAO, NLIB, WES2, YELL). Our processing strategy is still based on using fixed IGS weekly combined SP3 and ERP files and one station clock, usually ALGO, as a reference.

One major change to our processing strategy was made on June 17, 2001 (GPS week 1119), when we began applying loose constraints (10m apriori) to the 5 anchor stations while continuing to apply 100m apriori sigmas to the remaining stations. This change facilitated the integration and removal of constraints in the NAREF combination. Since GPS week 1113, we have been solving, whenever possible, phase integer ambiguities. This has resulted in an improvement of about 1mm in the east and height components of the station's coordinates when compared to the IGS cumulative SINEX solution. IGS recommended P1-C1 bias values v2.0 and v2.1 were implemented in January and May 2001 respectively and the IGS reference frame was changed to IGS00 on week GPS1143. Table 3 below summarizes some of the processing options. In addition to specifics presented in Table 3, a pre-processing strategy using precise point positioning is performed on all stations forming the regional network in order to remove station-satellite pairs showing poor data quality.

NRCan Ultra Rapid Processing Strategy and Changes

During 2001, NRCan continued the development and delivery of its Ultra Rapid Products (orbits and ERP) to the IGS Analysis Coordinator. About 80 IGS stations were routinely being downloaded on an hourly basis by the end of 2001 via ftp from CDDIS (Crustal Dynamics Data Information System), SOPAC (Scripps Orbit and Permanent Array Center), BKG (Federal Agency for Cartography and Geodesy, Germany) and the National Mapping Division of Geoscience Australia (formerly AUSLIG). Although only 35-40 stations were processed in each of our 3-hour sessions, a total of 45 to 55 different stations were usually combined into 48-hour arcs (using Normal Equations) since some core stations were not always available at the time of processing. The most significant changes to our Ultra Rapid processing strategy in 2001 are listed in Table 4. The reader is referred to the IGS 2000 Technical Report [1] for more details on the processing strategy used.

Results

This section shows the comparison of NRCan Ultra Rapid orbits and ERP products (EMU) with respect to the IGS Ultra Rapid (IGU) combination. Five graphics are presented for the year 2001. Figure 3 shows the orbit RMS, Median RMS and Weighted RMS (WRMS). The biggest spike in the WRMS graphic occured in mid-November 2001 and was present for all Centers. This problem, yet unexplained, happens from time to time and to date, no means of detection have been developed. We can also observe a small but constant decrease in magnitude of all 3 RMS time series from the beginning to the end of 2001. Figures 4 and 5 show the EMU Translations, the Rotations and Scale with respect to IGU. All series, especially the Rotations, show a reduction in the noise level starting in mid-September corresponding to the time the pole estimates were improved. Finally, Figures 6 and 7 show the pole (Xp, Yp, Xp_{rate}, Yp_{rate} and LOD) comparison with respect to IGU for both the estimated and predicted portions of EMU respectively. As expected, the noise level was considerably reduced in all series after the improvement of the pole estimates.

Future Work

In the near future, we will investigate the possibility of estimating satellite clock corrections. Because of the current CPU limitations, hardware upgrades may be required to facilitate the implementation and speed up the production.

NRCan Ionospheric Product

During 2001, NRCan has continued to support the Ionosphere Pilot project as an Ionosphere Associate Analysis Centre (IAAC) and contributed daily global ionospheric maps to IGS. A new strategy for single-station estimation of station and satellite inter-frequency differential code biases (DCB) was implemented.   This new approach combined with multi-day averaging has resulted in NRCan production of more stable DCB time series. This change also allowed for an increase in the number of IGS tracking

stations included in our daily ionospheric grid map computation, raising the total from around 50 to 90-100. During ionospheric grid map computation, the introduction of a time dependent stochastic process for the combination of observed delays at ionospheric grid points has provided flexibility to adjust the grid point averaging period and update the ionospheric maps at variable time intervals, making the processing approach more suitable for near real-time operations. Nevertheless, the stochastic model used for spatial averaging still requires improvement for NRCan to offer ionospheric grid maps that contribute more significantly to the IGS combination. Finally, to assist in assigning proper weights to the various IAAC's contributing to the combination, NRCan continues to daily evaluate the relative precision of the IAAC grid maps and submits validation files for use in the combination process.

Table 1: Final/Rapid Processing Strategies Modifications

GPS Week	Modification
1097	Adoption of new set of <P1-C1> bias values (v2.0) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.
1100	Implementation of precise point positioning (fixing IGU orbits and clocks) to validate stations carrier phase and pseudorange observations for Rapid solution. This procedure was discontinued after week 1110 due to problems arising from limitations in the accuracy of ultra-rapid clock estimations.
1106	Adoption of new set of <P1-C1> bias values (v2.1) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.
1121	Began applying sub-daily (12h/24h) ocean tides in the transformation from inertial to Earth-fixed coordinates (sp3) as recommended by IGS/IERS.
1139	Implementation of JPL's GIPSY-OASIS Version 2.6 software for Final solution.
1142	Estimation of Rapid clock corrections at 5 minute intervals (RINEX clock format).
1142	Implementation of JPL's GIPSY-OASIS Version 2.6 software for Rapid solution.
1143	Adoption of IGS00 (IGS realization of ITRF 2000) station coordinates and velocities.
1145	Re-aligned NRCan UT1-UTC value to VLBI derived value (Bulletin A) on day 0 and then resumed normal daily estimation procedure for UT1-UTC.

Table 2: IGS97 to IGS00 discontinuities in NRCan Rapid products forGPS week 1157

Solutions	RX (mas)	RY (mas)	RZ (mas)	Sc (ppb)	TX (cm)	TY (cm)	TZ (cm)
	-Pmy	-PMx	DUT1				
NRCan Orbits	0.020	0.034	-0.0141		-0.059	-0.003	0.848
Sigma	0.021	0.029	0.027		0.045	0.098	0.165
NRCan EOP	0.010	0.022	-0.202				
Sigma	0.021	0.028	0.054				
NRCan Stations	-0.023	-0.037	-0.173	-0.957	-0.286	-0.276	2.648
Sigma	0.019	0.019	0.039	0.113	0.050	0.065	0.101
IGS Realization	-0.024	-0.004	-0.159	-1.451	-0.450	-0.240	2.600
Sigma	0.092	0.099	0.076	0.270	0.410	0.500	0.750

Note: NRCan results were estimated processing GPS week 1157 (March 10-16, 2002) using both IGS97 and IGS00 coordinates and velocities along with their associated sigmas.
IGS results refer to epoch 02-Dec-2001 (GPS week 1143-0)

Table 3: GIPSY Regional processing strategy summary

Software used :	JPL GIPSY-OASIS v2.5
Reference frame :	ITRF as defined in the IGS orbit SP3
Orbital parameter :	IGS combined orbits held fixed
Earth rotation parameters :	X and Y pole as well as UT1-UTC from IGS combined weekly solution fixed.
Modeled observable :	Undifferenced phase and code observable at 30 seconds and 15 degree cut-off angle.
Date sampling interval :	7.5 minutes
Troposphere :	Total zenith delay and gradient modeled as random walk (~0.3cm/sqrt (h)). Niell mapping function.
Ocean loading :	Scherneck model
Station coordinates :	Network free solution carried out using 5 anchor stations with 10m sigma and 100m sigma for other stations.
Ambiguities :	Partly resolved, remaining are estimated as real values
Satellite and Station clocks :	Modeled as white noise process. One H-Maser clock fixed and used as time reference, usually ALGO.

Table 4: Modifications to NRCan Ultra Rapid processing strategy in 2001.

Date	DOY	Description of Changes
Jan. 15, 2001	015	Automated satellite de-weighting implemented using current and past processing results such as ambiguity and orbital parameters standard deviations
Jun. 19, 2001	170	First 1-hr Troposphere Zenith Delays submitted to the IGS Tropospheric Working Group Coordinator
Jul. 12, 2001	193	Station selection improved (now uses a core list and a set of replacement stations)
Sep. 15, 2001	258	Pole estimates improved (now uses one offset and 1 drift for every 48-hr arc)
Oct. 18, 2001	291	ADDNEQ2 (Bernese 4.2) used for orbit and ERP improvement/determination
Dec. 02, 2001	336	Adoption of IGS00
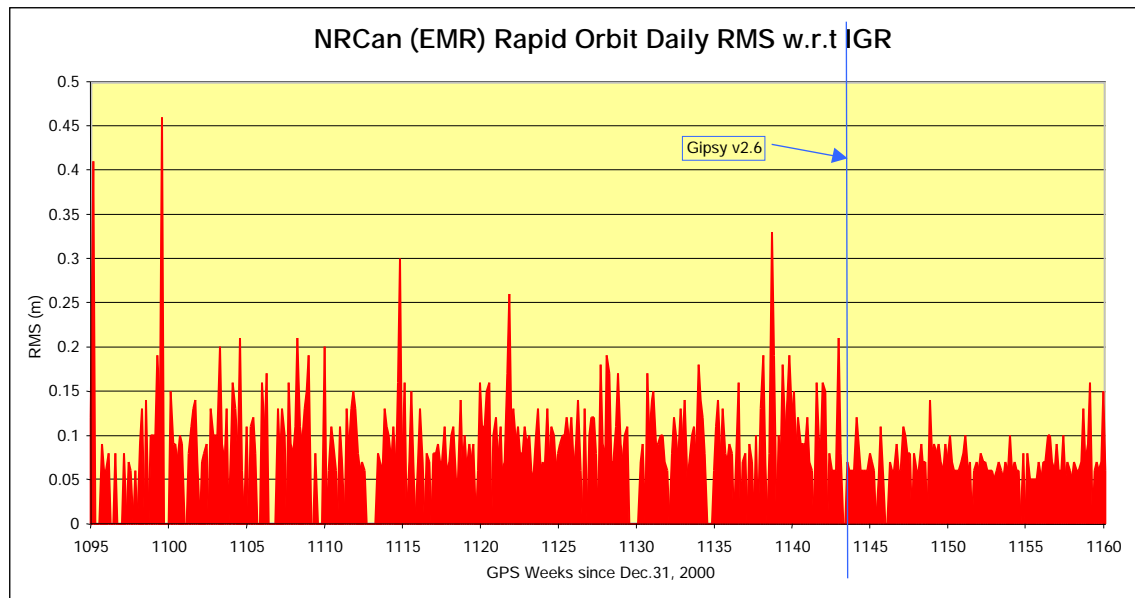
Figure 1: NRCan (EMR) Rapid orbit daily RMS w.r.t. IGR since Dec. 31, 2000
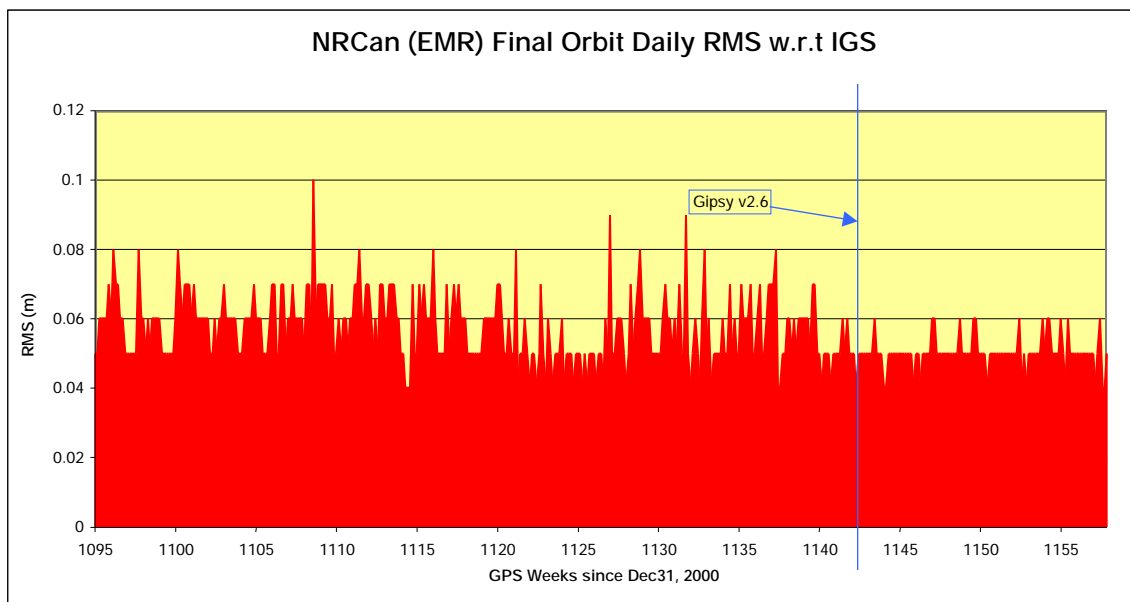
Figure 2: NRCan (EMR) Final orbit daily RMS w.r.t. IGS since Dec. 31, 2000
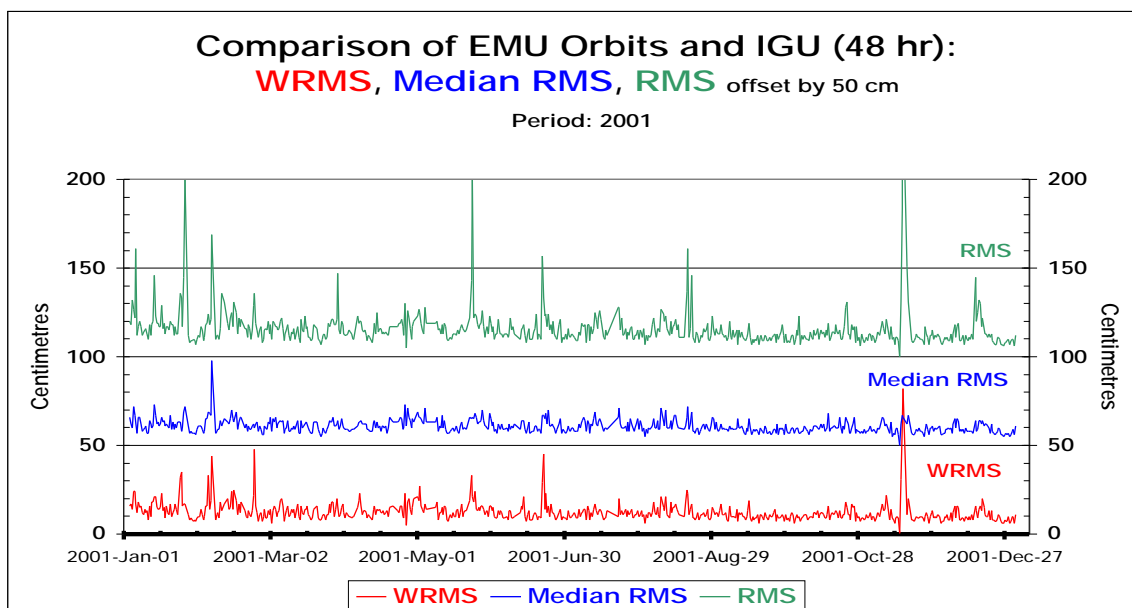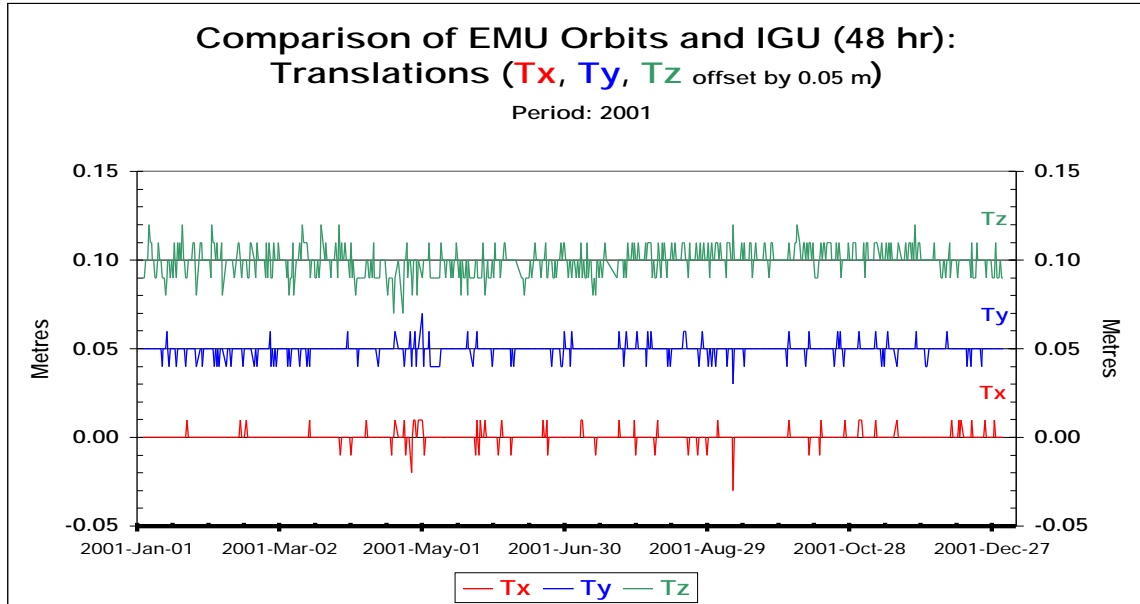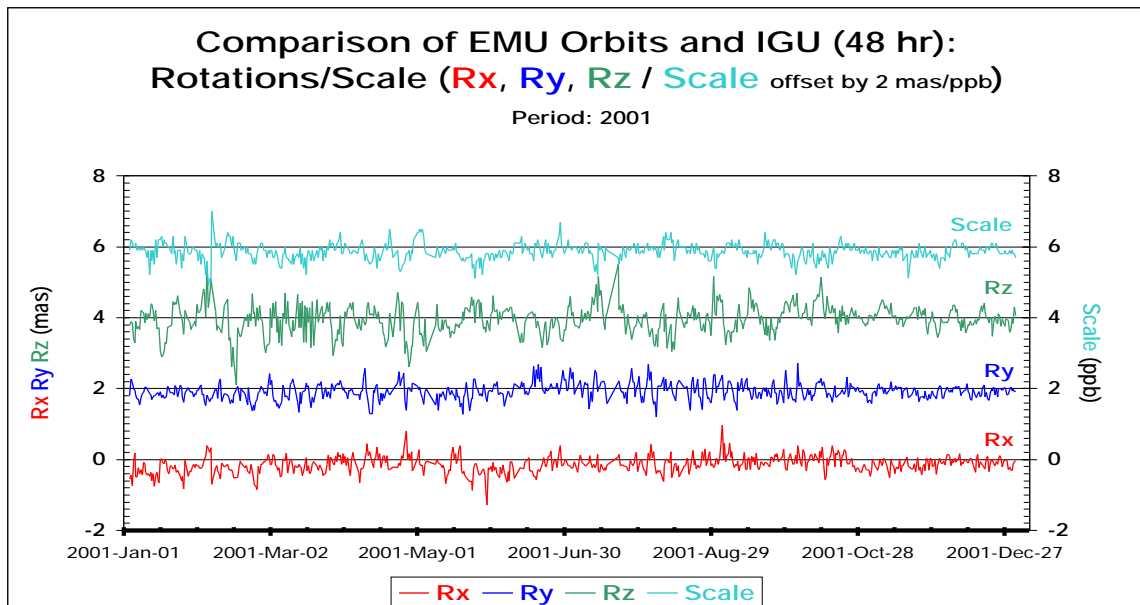

Figure 3:   Comparison of EMU Orbits and IGU for 2001 (48-hour Orbit): WRMS, Median RMS and RMS, each offset by 50 cm.

Figure 4: Comparison of EMU Orbits and IGU for 2001 (48-hour Orbit): Translations Tx, Ty and Tz, each offset by 0.05 m.

Figure 5: Comparison of EMU Orbits and IGU for 2001 (48-hour Orbit): Rotations Rx, Ry, Rz and Scale each offset by 2 mas, 2 mas, 2 mas and 2 ppb respectively.
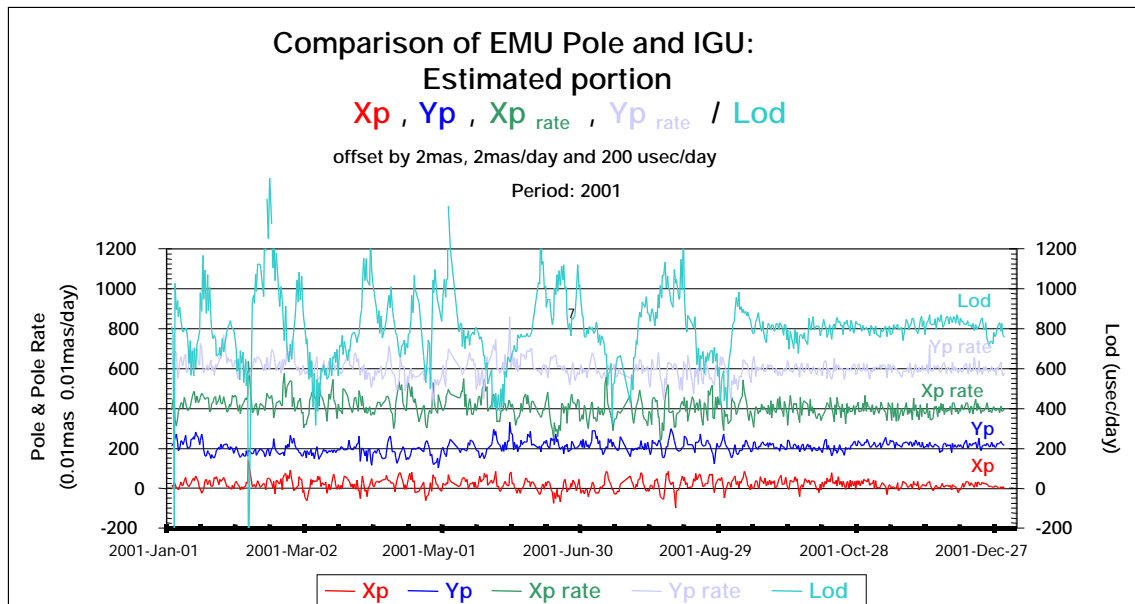
Figure 6: Comparison of EMU Estimated Pole and IGU for 2001: Xp, Yp, Xp_rate , Yp_rate and Lod, each offset by 2 mas, 2 mas, 2 mas/day, 2 mas/day and 200 usec/day respectively.
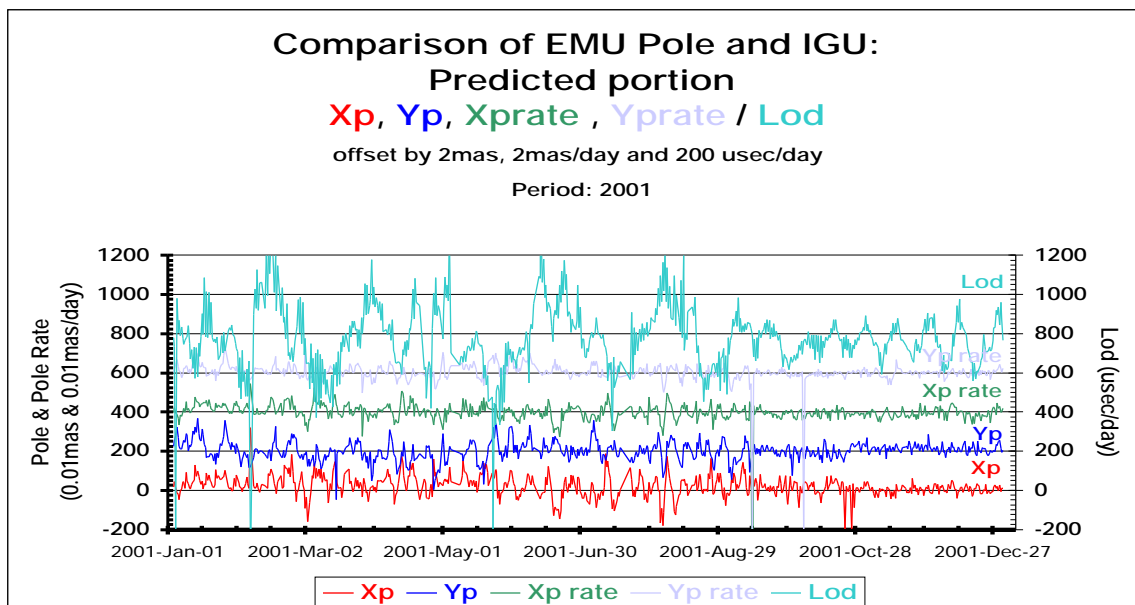

Figure 7: Comparison of EMU Predicted Pole and IGU for 2001: Xp, Yp, Xp_rate , Yp_rate and Lod, each offset by 2 mas, 2 mas, 2 mas/day, 2 mas/day and 200 usec/day respectively.

Acknowledgement

References

[1] P. Tétreault, Y. Mireault, B. Donahue , P. Héroux and C. Huot, NRCan IGS Analysis Report for 2000, in *IGS 2000 Technical Report*, edited by K. Gowey, R. Neilan and A. Moore, JPL/IGS Central Bureau, 11/2001, pp.111-116.

[2] B. Donahue, P. Héroux, C. Huot, D. Hutchison, J. Kouba, Y. Mireault and P. Tétreault, NRCan Analysis Center Contributions to the IGS, in *IGS Network, Data and Analysis Center Workshop 2002*, in print.